Interreg

Cofinanziato dall'Unione europea
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Marittimo–IT FR–Maritime

EPIC
UN MARE PRIVO DI PLASTICA

# Monitoraggio dall'alto delle plastiche in mare con droni e satelliti

## *Surveillance d'en haut des plastiques en mer avec drones et satellites*

Ing. Cinzia Licciardello
SIRA (Sistema Informativo Regionale Ambientale) - ARPAT

Sistema Nazionale per la Protezione dell'Ambiente

ARPAT
Agenzia regionale per la protezione ambientale della Toscana

REGIONE TOSCANA

# ARPAT - SIRA

**SI**stema Informativo **R**egionale **A**mbientale / *Système d'information Géographique Régional pour l'Environnement* (SIT, Remote Sensing & Data Analysis Specialists)

Pilotaggio droni ed elaborazione dati / *Pilotage de drones et élaboration des données:*

- 4 tecnici esperti / techniciens experts

Responsabile / *Directeur*

- Dirigente del Settore SIRA / *Directeur de secteur*

## Attività di progetto / Activités dans le project

(D2.1.1.1) Monitoraggio (aree di accumulo) / *Surveillance (accumulations des déchets)*

(D2.1.1.2) Monitoraggio (dinamiche di accumulo) / *Surveillance (evolution des déchets)*

**(D2.1.1.3) Caratterizzazione (UAS) / *Caractérisation (UAS)***

# Monitoraggio / *Surveillance*

## (A) Satelliti / *Satellites*

Monitoraggio globale / *Surveillance mondiale*
Dimensione oggetti / *Taille des objects*: 20m (gratuite / *gratuites*) - 50cm (a pagamento / *payantes*)

**Progetto Copernicus (free) / Projet Copernicus (gratuit)**

- direzione e velocità delle correnti / *direction et vitesse des courants* (Copernicus Marine Service - CMEMS)
- riprese ottiche multispettrali e radar / *Imagerie satellitaires multispectrales et radar*

**Satelliti commerciali (a pagamento) / Satellites commerciaux (payantes)**

- riprese ottiche multispettrali e radar / *Imagerie satellitaires multispectrales et radar*

## (B) Droni / *Drones*

Monitoraggio locale / *Surveillance locale*
Dimensione oggetti / *Taille des objects* >= 10cm

- riprese multi/iperspettrali, LiDAR, termiche / i*magerie multi/hyperspectrales, LiDAR, thermiques*

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EPIC UN MARE PRIVO DI PLASTICA

# (A) Evento/*Evénement* 05-06 maggio/*mai* 2026 (Arno – Marina di Pisa)

## Copernicus Sentinel-2 (10x10m)

02 maggio / *mai*

07 maggio / *mai*

09 maggio / *mai*

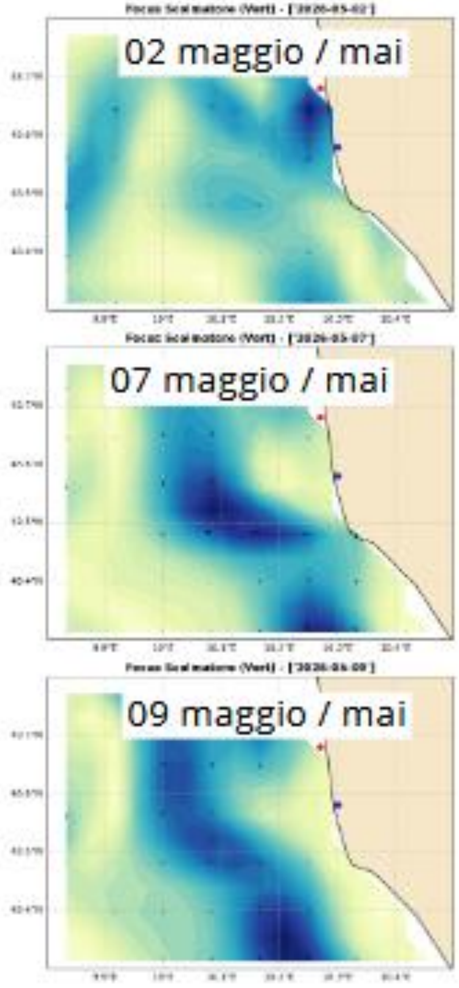
## Planet PlanetScope (3x3m)


02 maggio / *mai*


07 maggio / *mai*


12 maggio / *mai*

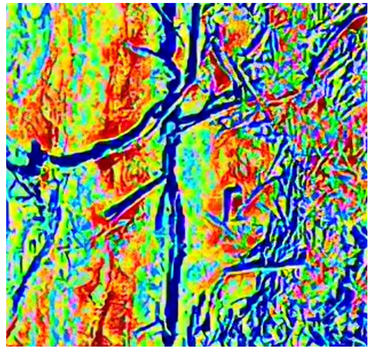
## Copernicus CMEMS – correnti / *courants*



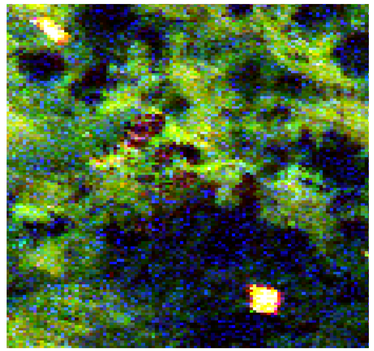

Velocità della Corrente Superficiale / *Vitesse des courants de surface*

# (B) Droni/*Drones*

Drones

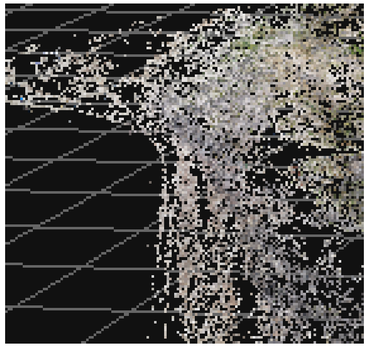


Camere termiche / *Imagerie thermiques*



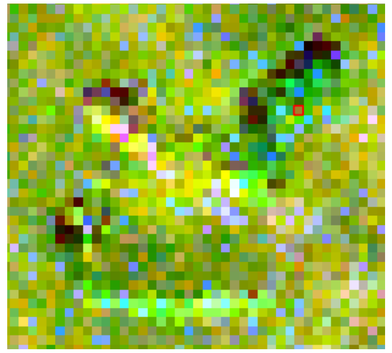
Camere iperspettrali / *Imagerie hyperspectrales*

Camere ottiche / *Imagerie optiques*

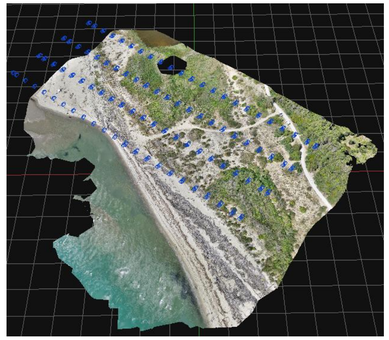


Lidar

Identificazione oggetti / *Identification des objects*



Caratterizzazione oggetti / *Caracterisation des objects*

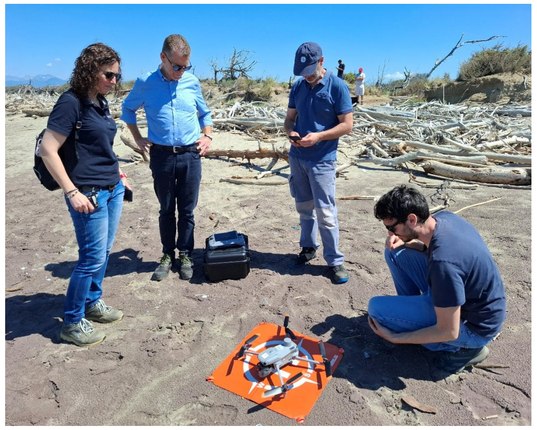


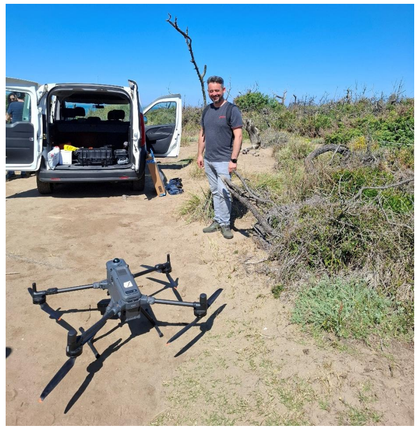
Modelli 3d / *Modèles 3d*

# Sistema di rilevamento / *Système de détection*

## Droni / *Drones*

DJI Matrice 400
DJI Matrice 4T
DJI Mini5
(GNSS)





## Sensori / *Capteurs*

- Integrated Cameras
- Integrated Thermal Cameras
- DJI ZenMuse L3 (LiDAR)
- FS60-C – Hyperspectral Camera (300 bands, 400-1.000nm)

LiDAR DJI ZenMuse L3

Camera iperspettrale FS60-C

## Personale e organizzazione / *Personnel et organisation*

- 4 piloti / *pilotes* A1-A3, A2, Specific
- 1 Dirigente / 1 *Directeur*
- Sistema di gestione / *Système de gestion*
- Linee guida SNPA(*) / *Guides* SNPA(*)

(*) Sistema Nazionale di Protezione Ambientale / *Système National de protection de l'environnement*



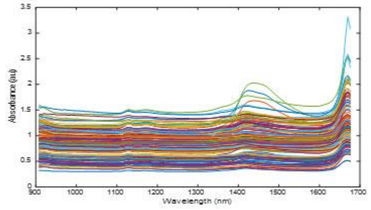
*Pubblicazioni tecniche SNPA 2025 – 978-88-448-1266-9*

# Caratterizzazione / *Caractérisation*

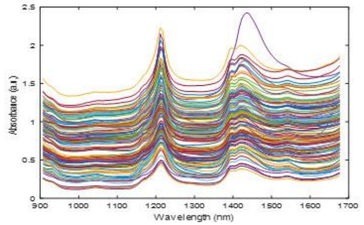
| **Obiettivo** *(Objectif)* | **Area di interesse** *(Zone d'intérêt)* | **Dati** *(Données)* | **Software** *(Logiciels)* |
|---|---|---|---|
| Valutazione delle potenzialità dei sensori iperspettrali UAS nelle bande VIS+NIR per la classificazione delle tipologie di macroplastiche spiaggiate a supporto alle attività di pulizia | Foce fiume Arno (Calambrone)<br>Foce fiume Serchio (Marina di Vecchiano)<br>Area tra le due foci (Gombo) | Dati *in situ*<br>Riprese iperspettrali (Drone) | QGIS<br>3D Zephyr (UAS)<br>Librerie Python (TensorFlow, Keras, PyTorch…) |
| *Evaluation des performances des capteurs hyperspectales visible et proche-infrarouge pour la classification des familles des déchets plastiques pour aider la planification du nettoyage des déchets* | *Embouchure du fleuve Arno (Calambrone)*<br>*Embouchure du fleuve Serchio (Marina di Vecchiano)*<br>*(Gombo)* | *Donnèès in situ*<br>*Images hyperspectrales (UAS)* | *QGIS*<br>*3D Zephyr (UAS)*<br>*Bibliothèques Python (TensorFlow, Keras, PyTorch…)* |

# Riflettività polimeri da riciclo / Réflectivité dels polymères recyclables

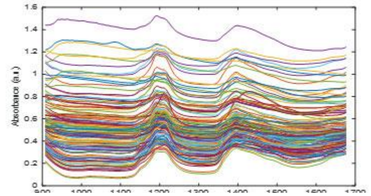
PET



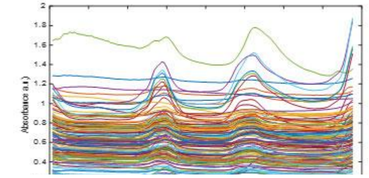
HDPI



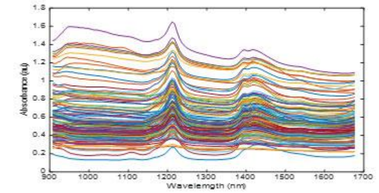
PP



PVC



LDPE



https://www.abcs.it/it/blog/caratterizzazione-materiali/classificazione-polimeri-da-riciclo

**Summary Cross Correlation Table**

| LIBRARY NAME | PE | PET | PP | PS | PVC |
|---|---|---|---|---|---|
| PE | **1.0000** | 0.1732 | 0.7764 | 0.3231 | 0.5736 |
| PET | 0.1732 | **1.0000** | 0.2314 | 0.6592 | 0.5551 |
| PP | 0.7764 | 0.2314 | **1.0000** | 0.3643 | 0.8100 |
| PS | 0.3231 | 0.6592 | 0.3643 | **1.0000** | 0.4762 |
| PVC | 0.5736 | 0.5551 | 0.8100 | 0.4762 | **1.0000** |
| **THRESH** | **0.9500** | **0.9500** | **0.9500** | **0.9500** | **0.9000** |

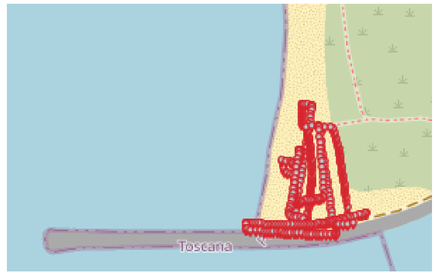
Buona separabilità tra PET e PP nella spettroscopia NIR (bande 900-1.700) /
*Bonne séparabilité du PET et PP avec spectroscopie NIR (bandes 900-1.700)*

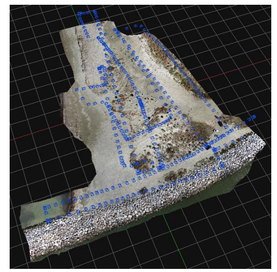
# 1. Caratterizzazione / *Caractérisation*

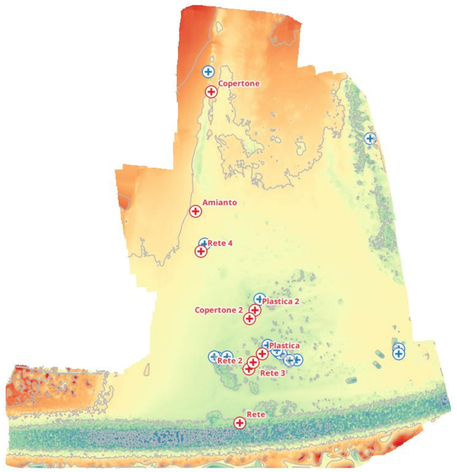
## Calambrone (marzo/*mars* 2025)

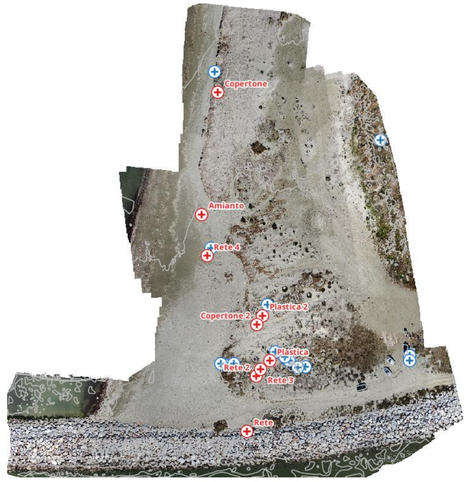
### Caratteristiche / Caractéristiques

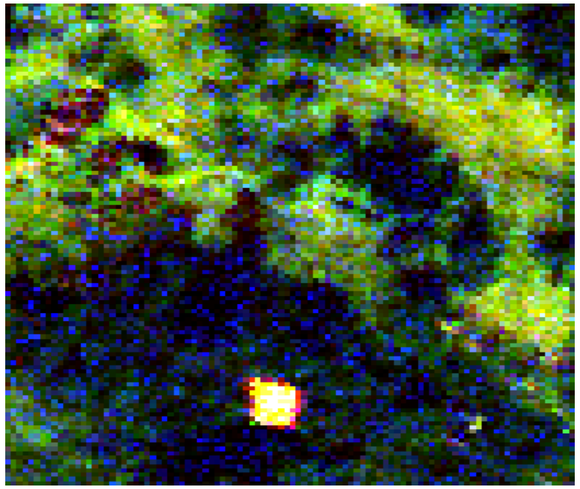
- Origine canale Arno / *Origine Arno canal*
- Correnti nord / *Courants nord*
- Dune / *Dunes*



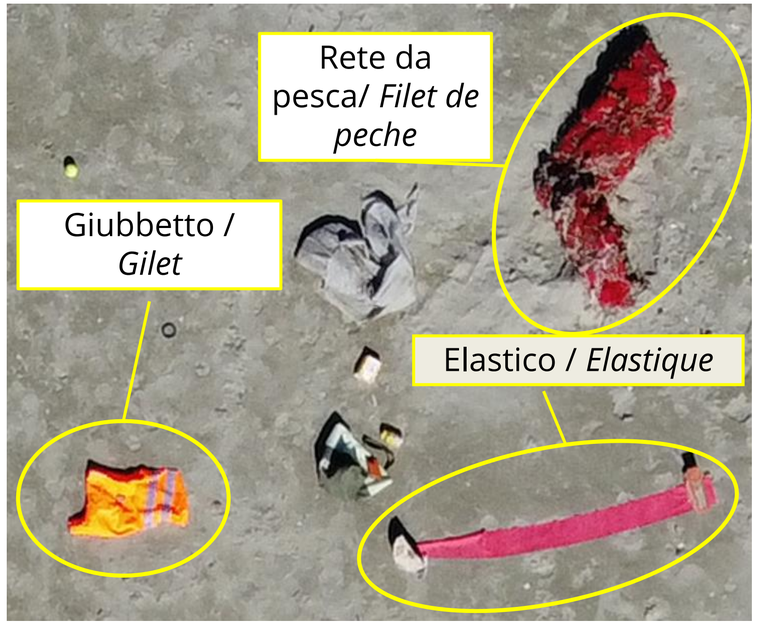


| Data / *Date* | Autore / *Auteur* | Droni e Sensori / *Drones et capteurs* | Prodotti / *Produits* |
|---|---|---|---|
| 5 marzo 2025 | ARPAT | DJI Mini2 | Ortoimmagine / *Othoimage* |
| | ARPAT/Microgeo s.r.l. | DJI Matrice 350 + FS60-C | Ortoimmagine 300 bande / *Orthoimage 300 bandes* |

# Rifiuti campione / *Exemples des déchets*




Dettaglio / *Détail* (DJI Mini2)

| Material | Absorpion Peaks | Sentinel-2 bands | PRISMA NIR bands | Albedo |
|---|---|---|---|---|
| PET | 326 nm<br>700 nm<br>711 nm<br>767 nm<br>823 nm<br>913 nm<br>1.046 nm | B5 (698-713 nm)<br>B8 (785-899 nm) | 33 (700 nm)<br>34 (711 nm)<br>40 (767 nm)<br>46 (823 nm)<br>56 (913 nm) | 0,7 |
| PP | 334 nm<br>703 nm<br>1,016 nm | B5 (698-713 nm) | 33 (703 nm) | |

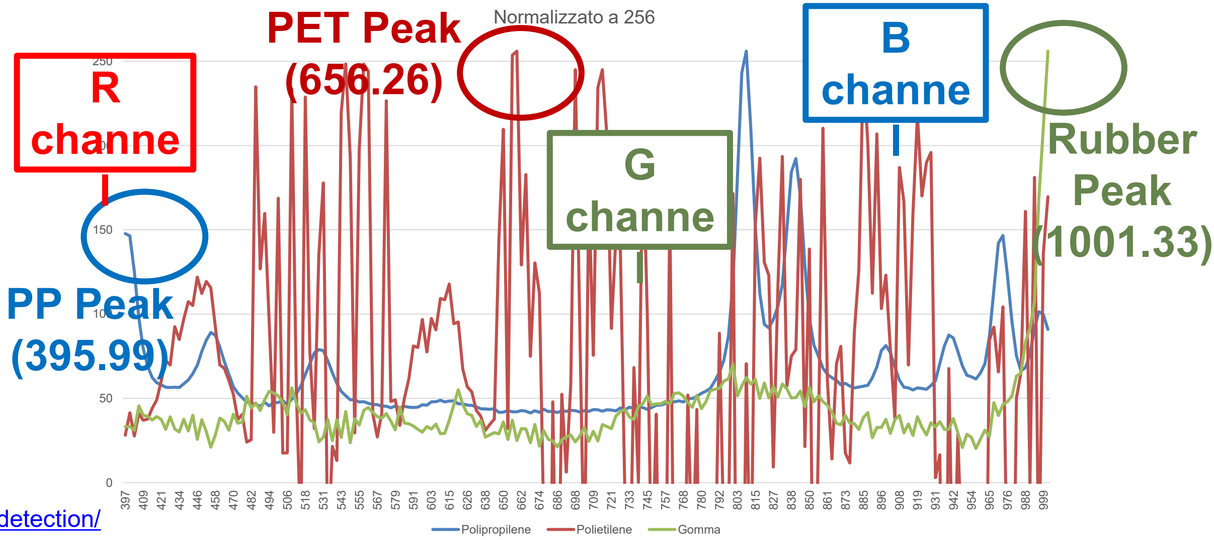

**SLoPP and SLoPP-E**
Raman Spectral Libraries for Microplastics Research

*Keenan Munno†, Hannah De Frond, Bridget O'Donnell and Chelsea Rochman*

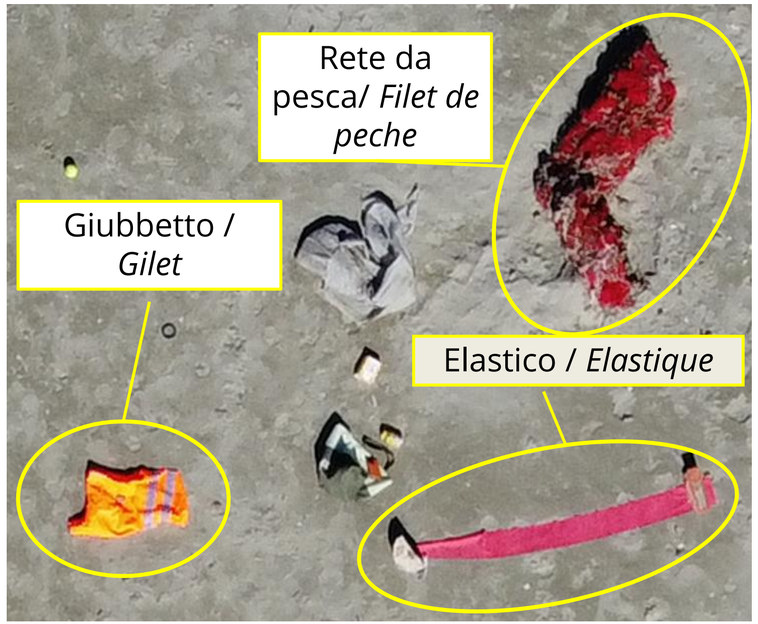
†keenan.munno@mail.utoronto.ca
Rochman Lab – University of Toronto

**'Big Five'**
PE - Polyethylene
PP – Polypropylene
PS – Polystyrene
PET – Polyethylene Terephtalate
PVC – Polyvinyl Chloride

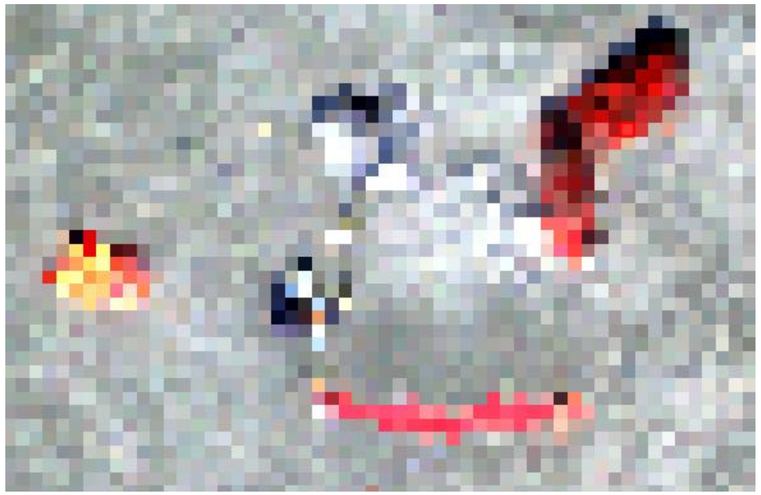
https://www.nirlab.com/comprehensive-catalogue-for-polymers-detection/



# Rifiuti campione / *Exemples des déchets*



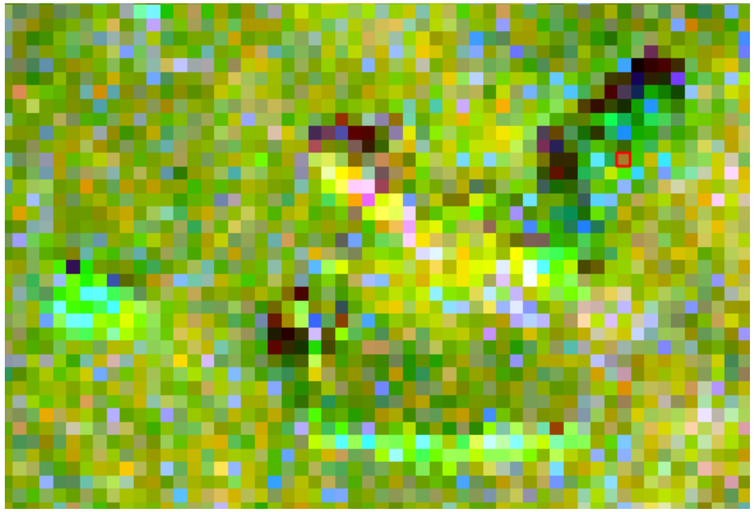

DJI Mini2



[129,80,44] (RGB)

λ = 660/560/485nm

**Sensore iperspettrale FS60-C (GSD = 5cm)**

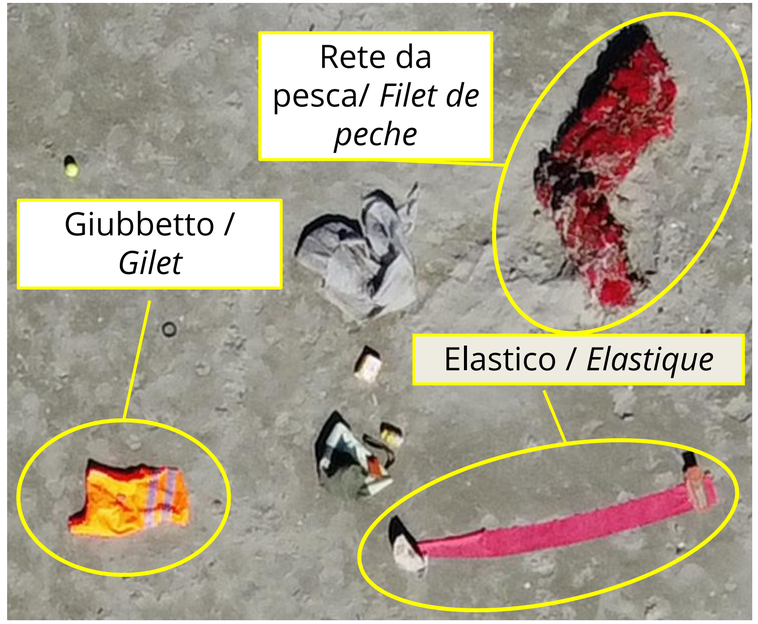


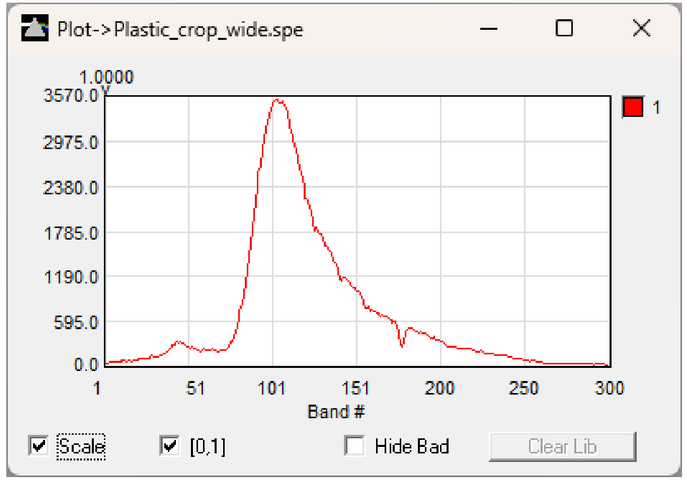
[2,127,299] (Plastic FCC)

λ = 396/656/1001 nm

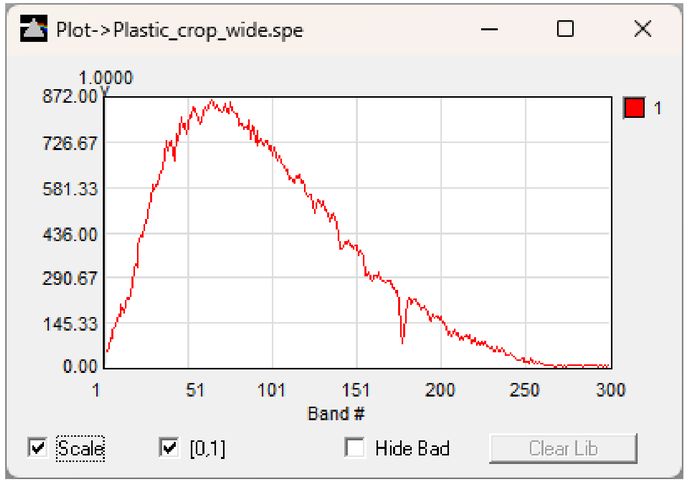
FS60-C Hyperspectral (GSD = 5cm)

# Bande spettrali / *Bandes spectrales*

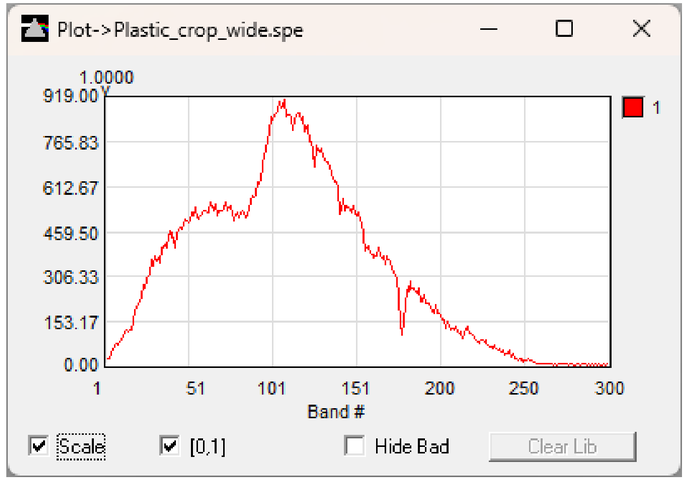


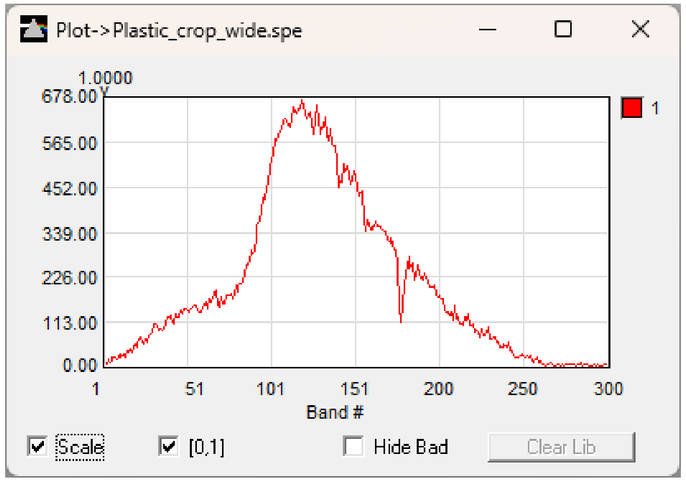

Giubbetto / *Gilet*




Busta / *Sac*

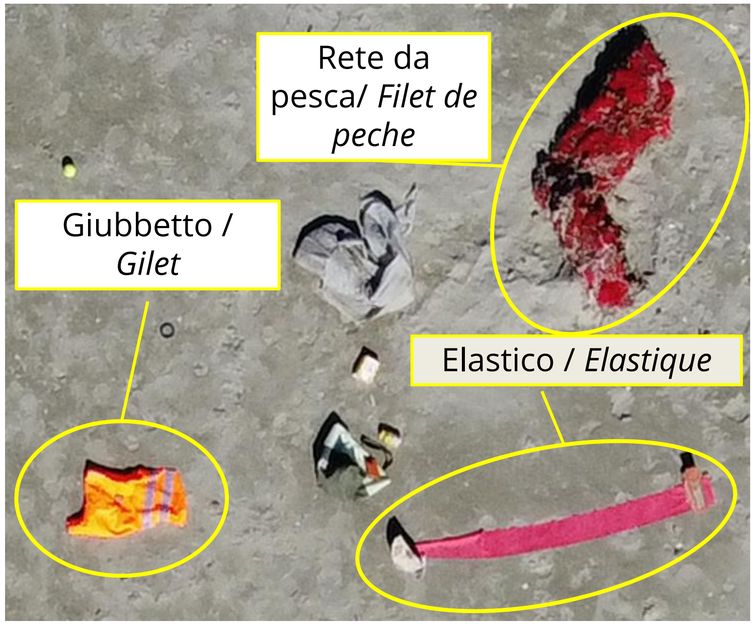


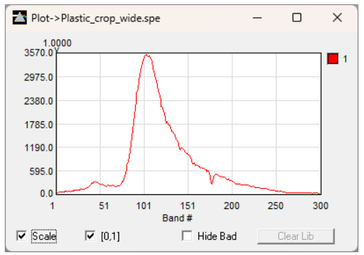

Elastico / *Elastique*



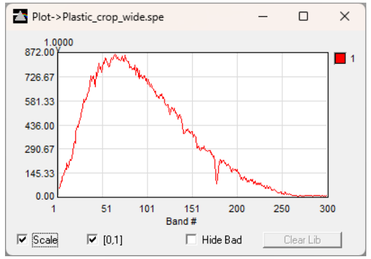

Rete da pesca / *Filet de peche*

# Separabilità / Séparabilité

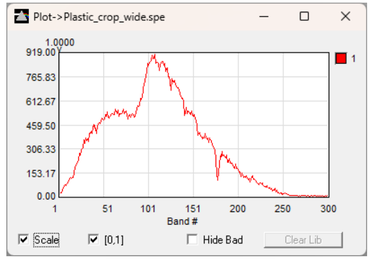


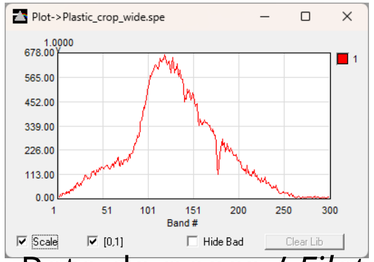

Giubbetto / *Gilet*



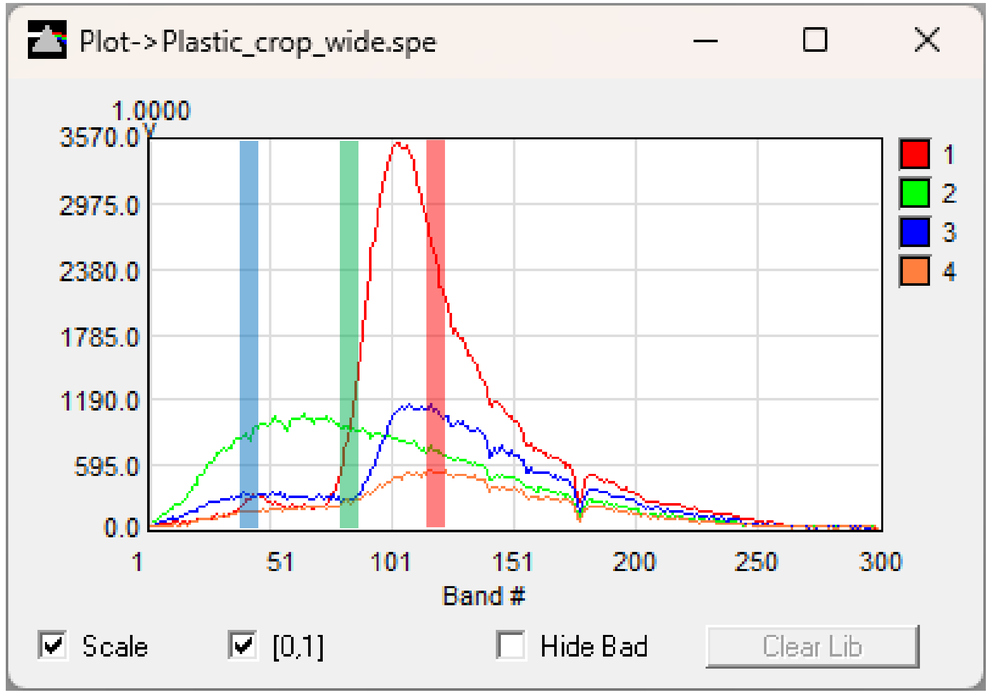

Busta / *Sac*




Elastico / *Elastique*



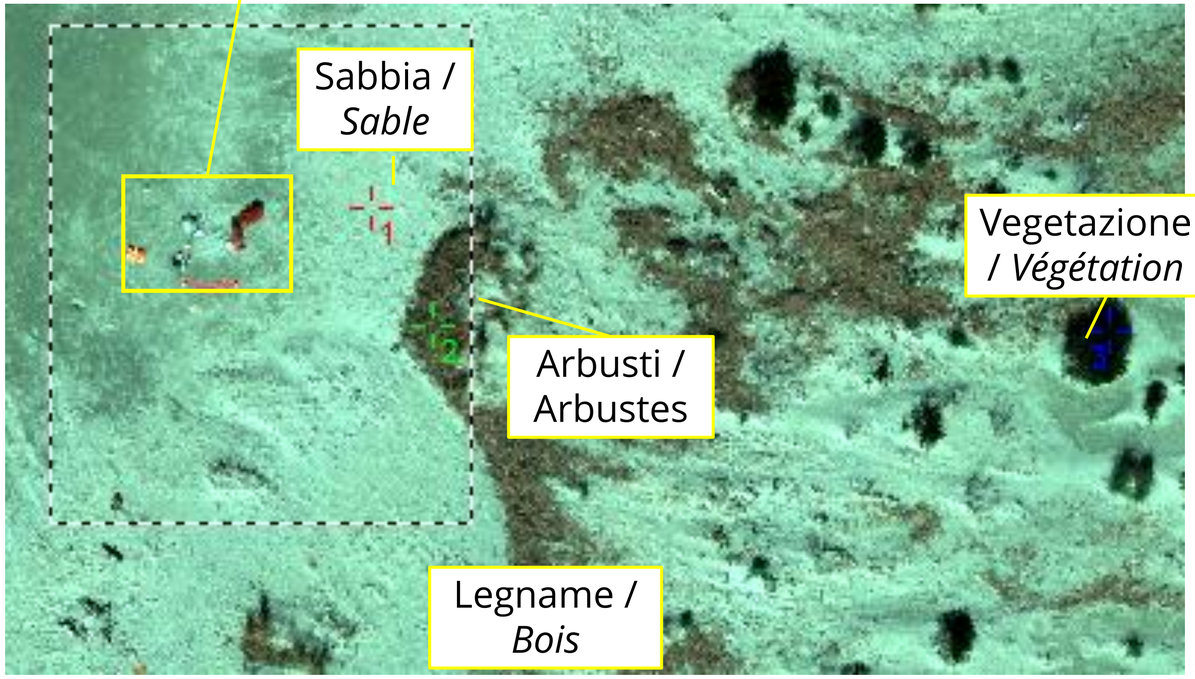

Rete da pesca / *Filet de peche*

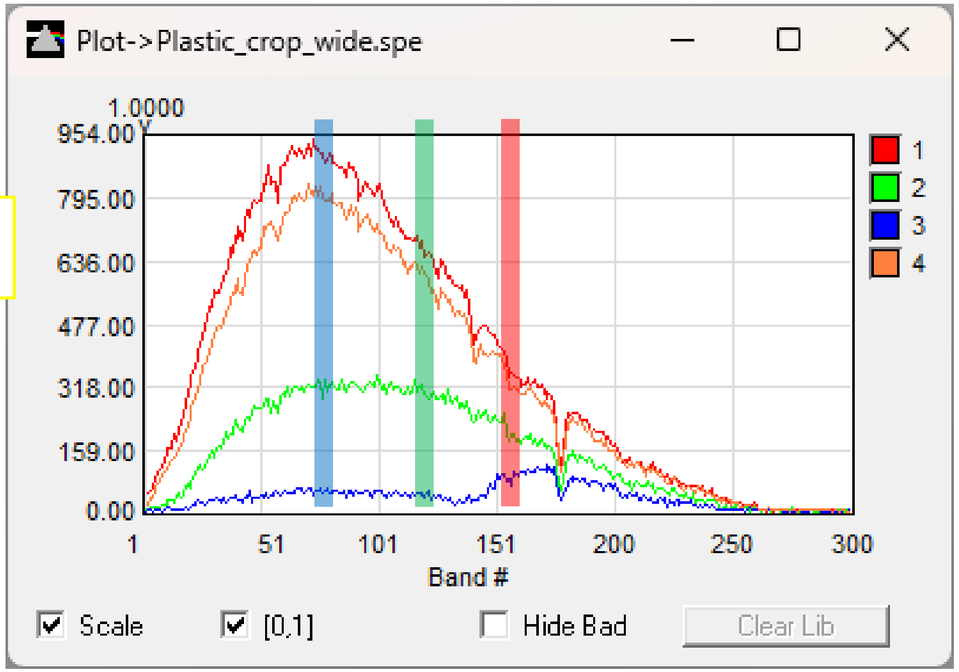



Giubbetto / *Gilet*
Busta / Sac
Elastico / *Elastique*
Rete da pesca / *Filet de peche*

| Oggetto | Materiale |
|---|---|
| Giubbetto / *Gilet* | (PES) Polyester |
| Busta / *Sac* | (PP) Polypropylene |
| Elastico / *Elastique* | Lattice<br>(TPE) Elastomer |
| Rete da pesca / *Filet de peche* | (HDPE) Polyethylene<br>(PP) Polypropylene<br>(PES) Polyestere |

# Ambiente / *Environnement*



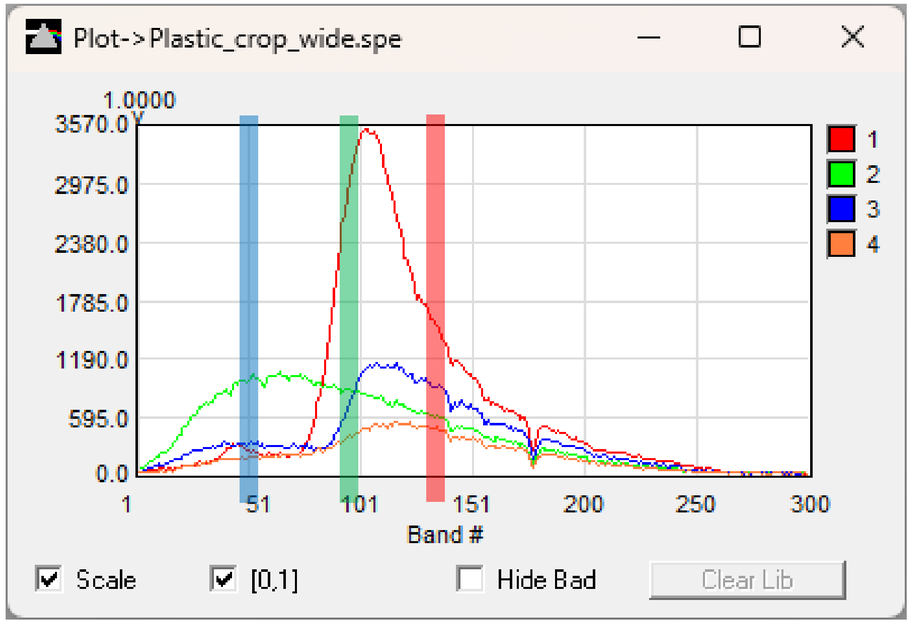




Sabbia / *Sable*
Arbusti / Arbustes
Vegetazione / Végétation
Legname / *Bois*

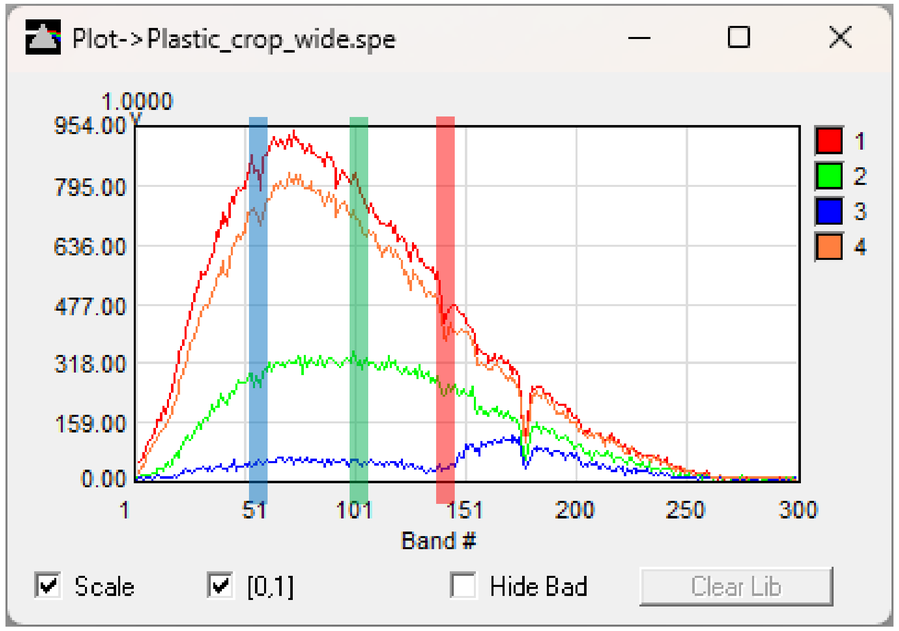
FS60-C Hyperspectral Camera

# Separabilità / *Séparabilité*

## Criticità / *Criticité* : arbusti / *arbustes*



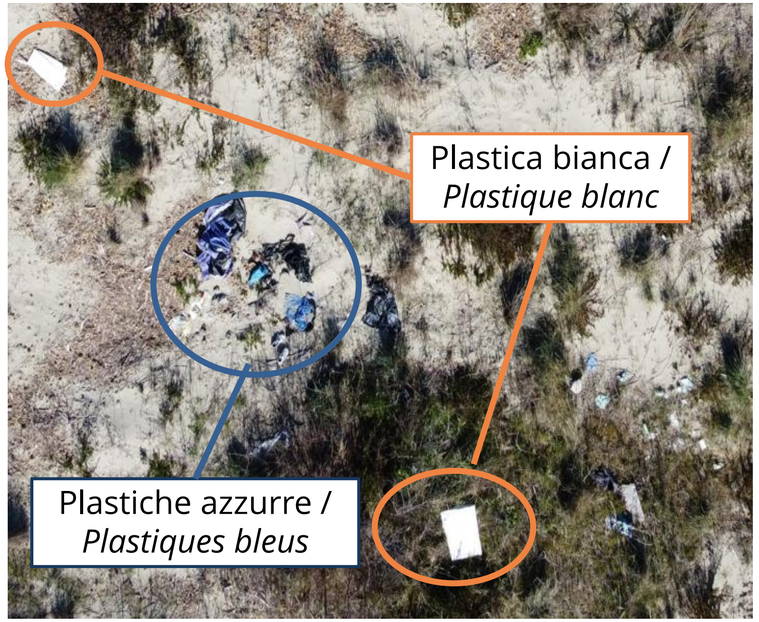

Giubbetto / *Gilet*
Busta / *Sac*
Elastico / *Elastique*
Rete da pesca / Filet de peche




Sabbia / *Sable*
Arbusti / Arbustes
Vegetazione / Végétation
Legname / *Bois*

FS60-C Hyperspectral Camera

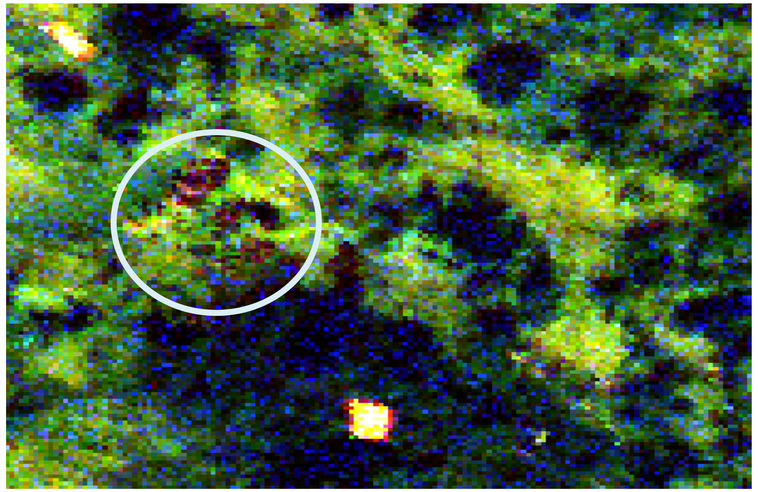
# 2. Rifiuti spiaggiati / *Déchets sur la plage*




DJI Mini2

[129,80,44] (RGB)

λ = 660/560/485nm



[2,127,299] (Plastic FCC)

λ = 396/656/1001 nm

FS60-C Hyperspectral (GSD = 5cm)

# Caratterizzazione / *Caractérisation*

| point_name | latitude | longitude | altitude | north | east | elevation |
|---|---|---|---|---|---|---|
| Rete | 43,58138 | 10,29604 | 48,04803 | 4826195 | 604637,3 | 48,04803 |
| Rete 2 | 43,58156 | 10,29609 | 47,87924 | 4826216 | 604640,8 | 47,87924 |
| Rete 3 | 43,58159 | 10,29611 | 47,89023 | 4826218 | 604642,5 | 47,89023 |
| Plastica | 43,58161 | 10,29616 | 48,03232 | 4826221 | 604646,1 | 48,03232 |
| Plastica 2 | 43,58177 | 10,29612 | 48,06063 | 4826239 | 604643,3 | 48,06063 |
| Rete 4 | 43,58198 | 10,29587 | 47,63848 | 4826261 | 604622,1 | 47,63848 |
| Copertone | 43,58253 | 10,29593 | 48,0911 | 4826323 | 604626,3 | 48,0911 |
| Copertone 2 | 43,58174 | 10,2961 | 47,77368 | 4826235 | 604641 | 47,77368 |

DJI M350RTK with FigSpec FS-50 Hyperspectral camera

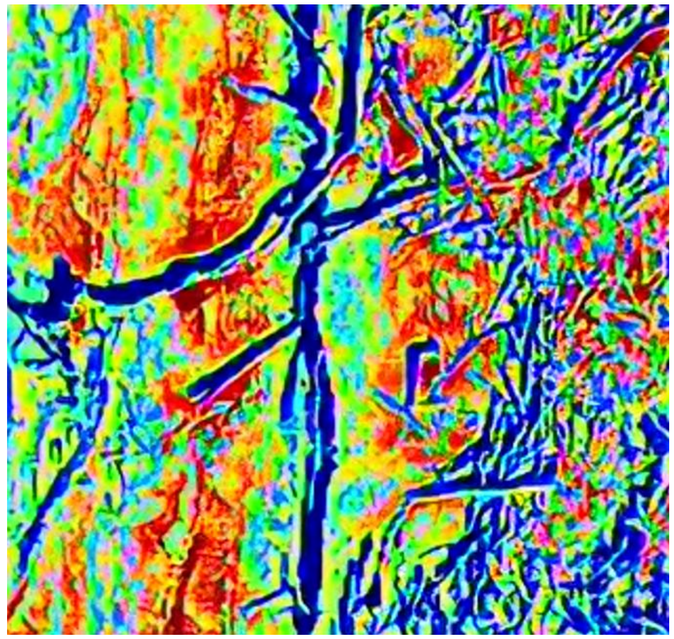
DJI Mini2 (onboard camera)

# 3. Area intermedia / *Zone intermédiaire*

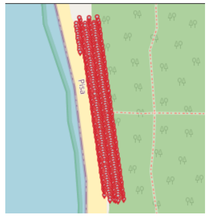
## Spiaggia di Gombo (maggio 2024 e maggio 2026 / *Plage de Gombo (mai 2024 et mai 2026)*

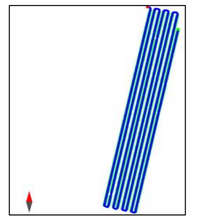
### Caratteristiche / Caractéristiques

- Origine correnti marine / *Origine courants marins*
- Correnti locali e nord / *Courants locales et nord*
- Dune / *Dunes*
- Legname / *Bois*



| Data / *Date* | Autore / *Auteur* | Droni e Sensori / *Drones et capteurs* | Prodotti / *Produits* |
|---|---|---|---|
| 14 Maggio 2024 | ARPA Lombardia | DJI Matrice 400 | Ortoimmagine + modello 3d / *Orthoimage et 3d Modèle* |
| | ISPRA | DJI Mavic 3M | |
| 22 Maggio 2026 | ARPAT - SIRA | DJI Matrice 400 + FS60-C | Ortoimmagine iperspettrale / *Orthoimage Hyperspectrale* |
| | ARPAT - SIRA | DJI Matrice 4T | Termografia e ortoimmagine / *Thermographie et Orthoimage* |



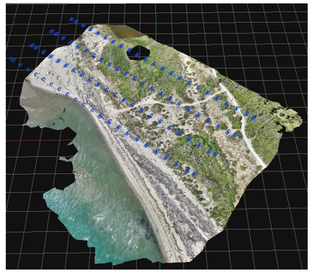


# 4. Fiume Serchio / *Riviére Serchio*

## Marina di Vecchiano (maggio 2026) / *(mai 2026)*

### Caratteristiche / Caractéristiques

- Origine fiume Serchio / *Origine Serchio fleuve*
- Correnti locali e nord / *Courants locales et nord*
- Dune / *Dunes*
- Legname / *Bois*

Smarphone Camera

DJI Matrice 400 + DJI ZenMuse L3 Camera

| Data / *Date* | Autore / *Auteur* | Droni e Sensori / *Drones et capteurs* | Prodotti / *Produits* |
|---|---|---|---|
| 22 Maggio 2026 | ARPAT - SIRA | DJI Matrice 400 + FS60-C | Ortoimmagine iperspettrale / *Orthoimage Hyperspectral* |
| | ARPAT - SIRA | DJI Matrice 400 + DJI ZenMuse L3 | Ortoimmagine e DSM LiDar / *Orthoimage et Modéle LiDAR* |

# Copertura del suolo / *Couverture du sol*

## 1. Spiaggia / *Plage*

- Dimensioni minori / *Petite taille*
- Fondo uniforme / *Fond uniforme*

## 2. Cumuli di legname / Tas de bois

- Dimensioni intermedie / *Moyenne taille*
- Fondo non uniforme / *Fond non uniforme*

## 3. Dune / Dunes

- Dimensioni maggiori / *Grand Taille*
- Fondo non uniforme / *Fond non uniforme*

# Elaborazione

## Aree / *Zones*

### Spiaggia / *Plage*
- Dimensioni minori / *Petite taille des plastiques*
- Fondo uniforme / *Fond uniforme*
- Influenza della pendenza / *Influence de la pente*

### Cumuli di legname / Tas des bois
- Dimensioni intermedie / *Taille moyenne des plastiques*
- Fondo non uniforme / *Pas de fond uniforme*
- Ombre / *Ombres*

### Vegetazione dunale / *Végétation dunaire*
- Dimensioni maggiori / *Grande taille des plastiques*
- Fondo non uniforme / *Pas de fond uniforme*
- Ombre / *Ombres*

## Tecniche / *Techniques*

### (0) Preprocessing
1. Area subdivision (sand/wood/brushes/trees)
2. Background/Shadow Removal
3. Band Stack:
   - RGB
   - Slope
   - NDVI (Vegetation Identification)
   - PCA or manually-selected Hyperspectral bands

### (1) Classification
- (A) Machine Learning (distance/SVM/RForest)
- (B) Deep Learning
  - Object Detection (YOLO v11) *(Objects Count)*
  - Segmentation (U-Net) *(Affected Areas)*

# Prossime attività / Prochaines activités

**(D2.1.1.1) Monitoraggio (aree di accumulo) / *Surveillance (accumulations des déchets)***

**(D2.1.1.2) Monitoraggio (dinamiche di accumulo) / *Surveillance (evolution des déchets)***

Attività / Activités:

1. Monitoraggio restrospettivo e nel corso di eventi meteo rilevanti tramite riprese satellitari / *Surveillance aver imagerie satellitaires des événements météolorologiques*

2. Collaborazione con CNR per lo studio delle dinamiche della distribuzione e delle aree di accumulo e per la caratterizzazione delle plastiche (rilievi UAS con camera iperspettrale e analisi di laboratorio) / *Collaboration avec CNR dans l'étude des areales d'accumulation des plastiques et la caracterisation des plastiques (drone avec capteur hyperspectrale et analyses en laboratoire)*

3. Supporto alle attività previste dalla Marine Strategy per il monitoraggio dei rifiuti spiaggiati e in mare (a integrazione delle attività del Progetto EPIC) / *Integration des activités du project Epic avec les activités de surveillance des plastiques pour la 'Marine Strategy'*

# Grazie per l'attenzione / *Merci pour votre attention*

**Contatti / *Contacts***

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